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4) Abstract Title
Cutter element

7) A cutter element (10) for use in a drill bit has a substrate (12) and a cutting layer (14). The substrate (12) cludes a grip portion (16) and an extension portion (18), the grip portion (16) having an insert axis (17) and e extension portion (18) including an interface surface (19) having a first apex (20). The cutting layer (14) is fixed to the interface surface (19) and has a cutting surface (15) having a second apex (22). The cutting layer 4) is shaped such that when a plane (P) passing through the first apex (20) and lying parallel to the insert axis 7) and normal to a radius from the insert axis (17) is defined, the plane (P) divides the cutting layer (14) into ajor and minor portions.

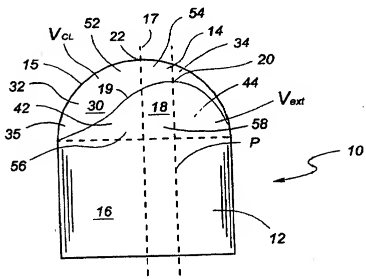

FIG 1

least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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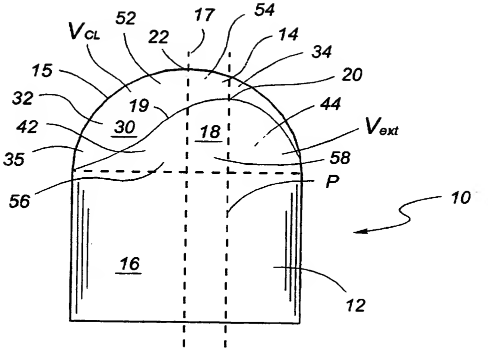

FIG 1

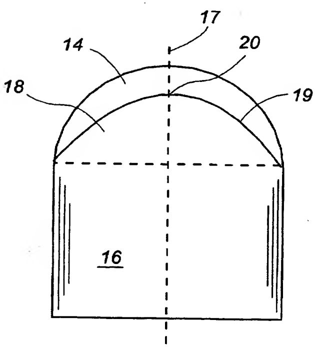

FIG 2
(Prior Art)

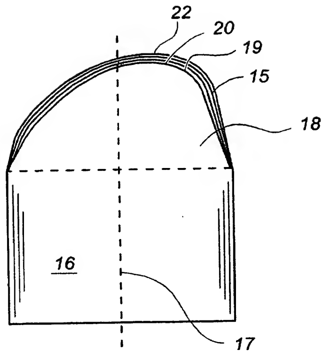

FIG 3
(Prior Art)

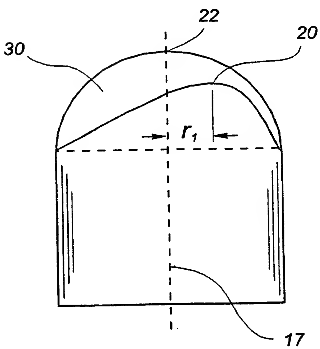

FIG 4

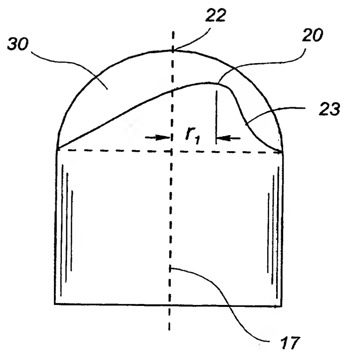

FIG 5

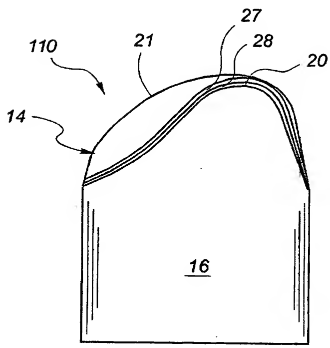

FIG 6

CUTTER ELEMENT

The present invention relates generally to a cutter element for use in earth-boring drill bits.

The present invention is concerned with increasing the life of cutter elements that comprise a layer of superhard material, such as diamond, affixed to a substrate. More particularly, in an embodiment the present invention relates to a polycrystalline diamond enhanced insert comprising a supporting substrate and a diamond layer supported thereon.

In a typical drilling operation, a drill bit is rotated while being advanced into a soil or rock formation. The formation is cut by cutting elements on the drill bit, and the cuttings are flushed from the borehole by the circulation of drilling fluid that is pumped down through the drill string and flows back toward the top of the borehole in the annulus between the drill string and the borehole wall. The drilling fluid is delivered to the drill bit through a passage in the drill stem and is ejected outwardly through nozzles in the cutting face of the drill bit. The ejected drilling fluid is directed outwardly through the nozzles at high speed to aid in cutting, to flush the cuttings and to cool the cutter elements.

The present invention is described in terms of cutter elements for roller cone drill bits, although its benefits can be realised in percussion bits as well as other fixed cutter bits. In a typical roller cone drill bit, the bit body supports three roller cones that are rotatably mounted

on cantilevered shafts, as is well known in the art. Each roller cone in turn supports a plurality of cutter elements which cut and/or crush the wall or floor of the borehole and thus advance the bit.

Conventional cutting inserts typically have a body consisting of a cylindrical grip portion from which extends a convex protrusion. In order to improve their operational life, these inserts are preferably coated with a superhard, sometimes also known as ultrahard, material. The coated cutting layer typically comprises a superhard substance, such as a layer of polycrystalline diamond (PCD), thermally stable diamond or any other ultrahard material. The substrate, which supports the coated cutting layer is normally formed of a hard material such as tungsten carbide (WC). The substrate typically has a body consisting of a cylindrical grip from which extends a convex protrusion. The grip is embedded in and affixed to the roller cone and the protrusion extends outwardly from the surface of the roller cone. The protrusion, for example, may be hemispherical, which is commonly referred to as a semi-round top (SRT), or may be conical, or chisel-shaped or may form a crest that is inclined relative to the plane of intersection between the grip and the protrusion. The latter embodiment, along with other non-axisymmetric shapes, is becoming more common, as the cutter elements are designed to provide optimal cutting for various formation types and drill bit designs.

The basic techniques for constructing polycrystalline diamond enhanced cutting elements are generally well known and will not be described in detail. They can be summarised as follows: a carbide substrate is formed

having a desired surface configuration; the substrate is placed in a mould with a superhard material, such as diamond powder and/or a mixture of diamond with other material that forms transition layers, and subjected to high temperature and pressure, resulting in the formation of a diamond layer bonded to the substrate surface.

Although cutting elements having this configuration have significantly expanded the scope of formations for which drilling with diamond bits is economically viable, the interface between the substrate and the diamond layer continues to limit usage of these cutter elements, as it is prone to failure. Specifically, it is not uncommon for diamond coated inserts to fail during cutting. Failure typically takes one of three common forms, namely spalling/chipping, delamination, and wear. External loads due to contact tend to cause failures such as fracture, spalling, and chipping of the diamond layer. The impact mechanism involves the sudden propagation of a surface crack or internal flaw initiated on the PCD layer, into the material below the PCD layer until the crack length is sufficient for spalling, chipping, or catastrophic failure of the enhanced insert. On the other hand, internal stresses, for example thermal residual stresses resulting from manufacturing process, tend to cause delamination of the diamond layer, either by cracks initiating along the interface and propagating outwards, or by cracks initiating in the diamond layer surface and propagating catastrophically along the interface. Excessively high contact stress and high temperature, along with a very hostile downhole operation environment, are known to cause severe wear to the diamond layer of cutting elements in percussion bits. The wear mechanism occurs due to the

relative sliding of the PCD relative to the earth formation, and its presence as a failure mode is related to the basic bit type and abrasiveness of the formation, as well as other factors such as formation hardness or strength and the amount of relative sliding involved during contact with the formation. Wear is not a typical failure mode in roller cone drill bits that utilise conventional diamond coated cutting elements. Instead, fatigue and impact of the diamond coating are the typical failure modes found.

One explanation for failure resulting from internal stresses is that the interface between the diamond and the substrate or a transition layer is subject to high residual stresses resulting from the manufacturing processes of the cutting element. Specifically, because manufacturing occurs at elevated temperatures, the differing coefficients of thermal expansion of the diamond and substrate material result in thermally-induced stresses as the materials cool down from the manufacturing temperature. These residual stresses tend to be larger when the diamond/substrate interface has a smaller radius of curvature. At the same time, as the radius of curvature of the interface increases, the application of cutting forces due to contact on the cutter element produces larger debonding and other detrimental stresses at the interface, which can result in delamination. In addition, finite element analysis (FEA) has demonstrated that during loading, high stresses are localised in both the outer diamond layer and at the diamond transition-layer/tungsten carbide interface. Finally, localised loading on the surface of the inserts causes rings or zones of tensile stress, which the PCD layer is not capable of handling.

In drilling applications, the cutting elements are subjected to extremes of temperature and heavy loads when the drill bit is in use. It has been found that during drilling, shock waves may rebound from the internal planar interface between the two layers and interact destructively.

All of these phenomena are deleterious to the life of the cutting element during drilling operations. More specifically, the residual stresses, when augmented by the repetitive stresses attributable to the cyclical loading of the cutting element by contact with the formation, may cause spalling, fracture and even delamination of the diamond layer from the substrate. In addition to the foregoing, state of the art cutting elements can lack sufficient diamond volume to cut highly abrasive formations, as the thickness of the diamond layer tends to be limited by the resulting high residual stresses and the difficulty of bonding a relatively thick diamond layer to a curved substrate surface. For example, even within the diamond layer, residual stresses arise as a result of temperature changes. Because these stresses typically increase as the thickness of the layer increases, this factor tends to be viewed as limiting on thickness.

According to a first aspect of the present invention, there is provided a cutter element for use in a drill bit, the cutter element comprising: a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and, a superhard cutting layer affixed to the extension portion, the cutting layer covering the

substrate apex and defining an interface surface on the extension portion, the interface surface being free of edges underneath the cutting layer, the cutting layer having a cutting surface that defines a cutting apex; wherein the cutting layer and the extension portion have a shape such that a plane can be passed through the insert axis to divide the cutting layer where the volume of the cutting layer on a first side of the plane is at least 60 percent of the total volume of the cutting layer.

According to a second aspect of the present invention, there is provided a cutter element for use in a drill bit, the cutter element comprising: a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and, a superhard cutting layer affixed to the extension portion to define an interface surface on the extension portion and having a cutting surface; wherein the cutting layer and the extension portion have a shape such that a plane can be passed through the insert axis to divide the cutting layer such that the volume of cutting layer on one side of the plane is at least 60 percent of the total volume of the cutting layer and wherein the cutting surface is axisymmetric.

According to a third aspect of the present invention, there is provided a cutter element for use in a drill bit, the cutter element comprising: a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and, a superhard cutting layer affixed to the extension portion to define an interface surface on the extension portion and having a cutting surface; wherein the

cutting layer and the extension portion have a shape such that a plane can be passed through the insert axis to divide the cutting layer such that the volume of cutting layer on one side of the plane is at least 60 percent of the total volume of the cutting layer and wherein the cutting surface is free of cutting edges.

According to a fourth aspect of the present invention, there is provided a cutter element for use in a drill bit, the cutter element comprising: a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and, a superhard cutting layer affixed to the extension portion to define an interface surface on the extension portion and having a cutting surface defining a cutting apex; wherein the cutting layer and the extension portion have a shape such that a plane can be passed through the insert axis to divide the cutting layer such that the volume of the cutting layer on a first side of the plane is at least 75 percent of the total volume of the cutting layer.

According to a fifth aspect of the present invention, there is provided a cutter element for use in a drill bit, the cutter element comprising: a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and, a superhard cutting layer affixed to the extension portion so as to define an interface surface on the extension portion and having a cutting surface defining a cutting apex that is offset from the substrate apex, the cutting layer covering the substrate apex; wherein the substrate and the cutting layer have a shape

such that the insert axis does not pass through the substrate apex and such that a plane parallel to the insert axis can be passed through the substrate apex to divide the cutting layer such that the volume of the cutting layer on a first side of the plane is at least 75 percent of the total volume of the cutting layer.

According to a sixth aspect of the present invention, there is provided a cutter element for use in a drill bit, the cutter element comprising: a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and, a superhard cutting layer affixed to the extension portion, the cutting layer covering the substrate apex; wherein the substrate and the cutting layer have a shape such that a plane parallel to the insert axis and passing through the first apex divides the cutting layer such that the volume of the cutting layer on a first side of the plane is at least 60 percent of the total volume of the cutting layer; and, wherein the cutting surface is axisymmetric.

According to a seventh aspect of the present invention, there is provided a cutter element for use in a drill bit, the cutter element comprising: a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and, a superhard cutting layer affixed to the extension portion; wherein the substrate and the cutting layer have a shape such that a plane parallel to the insert axis and passing through the first apex divides the cutting layer such that the volume of the cutting layer on a first side of the plane is at

least 60 percent of the total volume of the cutting layer; and, wherein the cutting surface is free of cutting edges.

According to an eighth aspect of the present invention, there is provided a cutter element for use in a drill bit, the cutter element comprising: a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis, the extension portion having a volume V_{ext}; and, a superhard cutting layer affixed to the extension portion so as to define an interface surface on the extension portion and having a cutting surface defining a cutting apex, the entire cutting layer having a volume V_{cl}; the extension portion and the cutting layer being configured such that a plane $P*$ can be passed through the insert axis such that the ratio of the volume of the cutting layer on a first side of the plane $P*$ to the total volume on the first side of the plane ($V_{cl-1}*$: ($V_{ext-1}*$ + $V_{cl-1}*$)) is at least 60 percent and less than 98% and the same ratio ($V_{cl-1}*$: ($V_{ext-1}*$ + $V_{cl-1}*$)) is greater than a corresponding ratio on a second side of the plane ($V_{cl-2}*$: ($V_{ext-2}*$ + $V_{cl-1}*$)); and wherein the volume on the first side of the plane, $V_{cl-1}*$, is at least 60 percent of the the total cutting layer volume, V_{cl}.

According to a ninth aspect of the present invention, there is provided a cutter element for use in a drill bit, the cutter element comprising: a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and, a superhard cutting layer affixed to the extension portion so as to define an interface surface and having a chisel-shape cutting surface; wherein the substrate and the cutting layer have a shape such that a

plane that includes the insert axis divides the cutting layer such that the volume of the cutting layer on a first side of the plane is at least 60 percent of the total volume of the cutting layer.

The preferred embodiments of the present invention provide cutting elements that provide increased fatigue life, and/or impact resistance and/or wear resistance, without increasing the risk of spalling or delamination.

The preferred embodiment of the present invention provides a diamond cutting element with increased life expectancy. The preferred cutting element has an optimised substrate/coating interface and incorporates a region of exceptional thickness in its cutting layer. This region of thicker diamond on the cutting element is oriented so that it is the primary cutting surface and sustains the major loading while cutting the rock formation. The preferred diamond cutting element has several advantages. One advantage is that the exceptionally thick diamond region is stronger and more rigid, which significantly reduces localised deformation under loading. When the localised deformations are reduced, the associated Hertzian tensile stresses are reduced, which ultimately reduces or eliminates chipping and breaking of the diamond coating. Another advantage of the stronger, more rigid diamond layer region is that it reduces the bending stresses at the substrate/coating interface when the cutting surface is loaded, which reduces the potential for coating debonding and/or breakage. Yet another advantage is that substrate/coating interface is further away from the loaded cutting surface of the cutter element, therefore keeping the maximum shear stresses away from the substrate/coating

interface, which is typically a relatively weak part of a diamond coated cutter element. Still yet another advantage is that because the cutter element has thicker, greater volume of diamond on the cutting surface, a tougher diamond grade can be utilised. Generally, a diamond grade that has increased toughness over another grade also has less wear resistance and thus the increase in the volume of diamond material to wear away is beneficial. If an increase in toughness is not required, the overall wear resistance of the cutter element is improved just through the increased volume in the diamond in the contact region.

The preferred cutter element compensates for the resulting residual stresses that might otherwise be caused by a region of exceptional thickness by providing an interface geometry that balances the reduction in bending stresses associated with the region of increased thickness with the increase in interface delamination stresses resulting from a decreased radius of curvature. The interface is designed so that even without transition layers or a non-planar interface, the residual stress due to thermal mismatch is still minimised. More specifically, the preferred cutter element provides a region of exceptional thickness that has a preferred volume ratio to the volume of the cutting layer and provides a cutting layer that has a preferred volume ratio to the volume of the protrusion portion of the cutter element.

The region of exceptional thickness can be defined in terms of volume ratios of the cutting layer in various regions of the cutting surface, or can alternatively be defined in terms of the configurations of the substrate and cutting layers. In each instance, the cutter element can

have a variation in cutting layer thickness, such that the cutting layer in the region of the cutter element that is expected to receive the most wear is thicker than in other portions of the cutting surface.

For a detailed description of examples of preferred embodiments of the invention, reference will now be made to the accompanying Figures, wherein, except as indicated, the substrate and cutting layers are each shown in silhouette even when those silhouettes do not lie in a single plane, and wherein:

Figure 1 is a cross sectional view of an example of a cutting element constructed in accordance with a preferred embodiment of the invention;

Figures 2 and 3 are cross-sectional views of prior art cutter elements;

Figure 4 is a cross-sectional view of an example of a cutting element constructed in accordance with a second embodiment of the invention;

Figure 5 is a cross-sectional view of an example of a cutting element constructed in accordance with a third embodiment of the invention; and,

Figure 6 is a cross-sectional view of an example of a cutting element constructed in accordance with a fourth embodiment of the invention.

Referring initially to Figure 1, an example of a cutter element 10 constructed in accordance with a first embodiment of the invention comprises a hard substrate 12 and a cutting layer 14. Substrate 12 comprises a body having a grip portion 16 and an extension portion 18. Grip portion 16 is typically cylindrical, although not necessarily circular in cross-section, and defines a longitudinal insert axis 17. Extension portion 18 includes an interface surface 19 which has an apex 20. Cutting layer 14 is affixed to interface surface 19 and includes an outer, cutting surface 15, which has an apex 22. The cutting layer 14 and the substrate extension portion 18 make up the protrusion portion 35 of the cutter element 10. Substrate 12 is preferably comprised of cemented carbide, preferably tungsten carbide, and abrasive cutting layer 14 is preferably comprised of abrasive particles bonded to substrate 12. The abrasive particles are preferably polycrystalline diamond, which may be supplemented with cobalt, but may be any of the other superhard abrasives, such as cubic boron nitride, diamond composite, etc.

Referring briefly to Figure 2, in prior art cutter elements, the surface 19 of extension portion 18 of substrate 12 is often axisymmetric, so that the apex 20 of substrate surface 19 coincides with the insert axis 17. In other prior art cutter elements, such as that shown in Figure 3, the surface 19, whilst not axisymmetric, echoes the shape of the outer surface 15 of the cutting layer 14, so that the apex 20 of substrate surface 19 coincides with the apex 22 of cutting layer 14. As used herein, the term "apex" refers to the point on the surface in question that is farthest from the grip portion of the cutter element, as measured along the insert axis 17. If more than one point

or a surface is of equal distance from the grip along the insert axis 17, then the central or centroid of the points or surface is considered as the apex. Although determination of the apex is made with respect to measurement along the insert axis, it will be understood that the apex of a surface does not necessarily lie on the insert axis 17 (see Figure 3). Similarly, the term "coincide" is used to refer to points that lie on a line parallel to the insert axis, or on the axis itself. In each of the prior art types of cutter elements mentioned above, the shape of the cutting layer 14 has been limited by the inability to manufacture cutting layers thicker than a certain maximum thickness because of the residual stresses resulting from the manufacturing process.

Referring again to Figure 1, the substrate apex 20 of the present cutter element does not coincide with the apex 22 of the cutting layer 14. Because the substrate apex 20 does not coincide with the cutting layer apex 22, a region of increased cutting layer thickness 30 is formed. The thickest portion of region 30 preferably does not coincide with either the insert axis 17 or the apex 22 of the cutting layer 14. Likewise, the cutting layer apex 22 may, but does not have to, coincide with the insert axis 17 and the cutting surface 15 of cutting layer 14 may, but does not have to, be axisymmetric. It is preferred but not necessary that the cutting surface 15 have a shape or contour such that it is free of cutting edges before use. It is recognised that certain wear patterns may ultimately cause the appearance of edges on the cutting surface, but these later-developed edges are not precluded by the present concept.

Further examples illustrating some of the embodiments reflecting these variations are shown in Figures 4 and 5. In the example of Figure 4, apex 20 is shifted away from insert axis 17 by a distance r_1, while cutting surface 15 remains hemispherical and apex 22 remains coincident with insert axis 17. In Figure 5, apex 20 is again shifted away from insert axis 17 by a distance r_1, whilst apex 22 remains coincident with insert axis 17, but substrate surface 19 has been modified to include a concave portion 23.

Figure 6 depicts a chisel insert 110 having an inclined crest 21, in which substrate apex 20 is shifted away from insert axis 17. As shown in Figure 6, a preferred embodiment includes at least one, and sometimes more preferably two, transition layers 27,28 between the cutting layer and the substrate. It is preferred that the cutting layer 14 cover the substrate apex 20. In addition, the substrate, transition layers and cutting layer preferably have a shape such that at least 60 percent, and more preferably 75 percent, of the total cutting layer lies on one side of a plane that includes the insert axis.

In each instance, it is preferred that cutting surface 15 be "contoured" or "sculpted", such that the cutting surface 15 is substantially free of cutting edges. In some embodiments, it is also preferred that the substrate surface also be contoured. The term "contoured" is intended to describe those surfaces that can be described as continuous curves. Portions of the continuous curve may be linear. The hemispherical, or SRT, shape is one such contoured surface. It is further preferred that the interface between the substrate and the cutting layer be

free of ridges or edges. One meaning of the phrase "free of cutting edges" is intended to exclude, along with surfaces that do not define a continuous curve, those curves having a radius of curvature less than 0.060 inches (approx. 1.5mm).

It has been found that a cutting layer that is free of cutting edges will be more impact resistant and thus have a longer expected life. Similarly, contouring the interface and cutting surfaces improves fatigue resistance and reduces internal residual stresses. Hence, a preferred embodiment of the present inserts includes contoured surfaces on both the substrate and the cutting layer.

In each of the foregoing embodiments, it is possible to divide the cutting layer 14, the protrusion portion 35 and the extension portion 18 into two parts, by defining a plane passing through cutter element 10. The cutter element can be described in terms of such a plane and specifically a plane passing through the substrate apex 20 and lying parallel to the insert axis 17 and normal to the radius r_1. The radius r_1 is defined geometrically as the line constructed perpendicularly from insert axis 17 to apex 20. In Figures 1 and 4-6, such a plane is normal to the plane of the paper as drawn. Referring again to Figure 1, this plane is labelled P and divides cutting layer 14 into a major portion 32 and a minor portion 34. Likewise, the plane divides protrusion portion 35 into a first section 42 and a second section 44. The volume of cutter layer material in each cutting layer section 32,34, and the volume of cutter protrusion in each protrusion section 42,44 can be calculated. For ease of description, these volumes are referred to as V_{cl-1}, V_{cl-2}, V_{p-1} and V_{p-2},

respectively (Figure 1). Similarly, the volume of the entire cutting layer 14 ($V_{cl-1} + V_{cl-2}$) is referred to as V_{cl} and the volume of the protrusion 35 ($V_{p-1} + V_{p-2}$) is referred to as V_p. Using the foregoing definitions, another preferred embodiment of the present invention can be described as a cutter element having a substrate surface and a cutting layer that have a shape such that the ratio of the volume of the major portion cutting layer to the total volume of the cutting layer (V_{cl-1}/V_{cl}) is at least 60 percent and more preferably about 62 percent. It is contemplated that in certain embodiments the ratio is preferably at least 65 percent and more preferably 75 percent. It is generally also preferred that the ratio (V_{cl-1}/V_{cl}) be less than 98 percent, and more preferably less than 80 percent. This configuration ensures that the diamond layer forms a cap over substrate apex. Alternatively, and more preferably in addition, it is preferred that the ratio V_{cl} : V_p be at least 18 percent and more preferably between 25 and 98 percent. It is important to note that since the apex may or may not coincide with the insert axis, the dividing plane in the above embodiment may or may not coincide with the insert axis.

Another embodiment of the present invention is defined in terms of a plane *P** that does pass through the insert axis. According to this embodiment, there exists a plane *P** through the insert axis 17 that divides cutting layer 14 into two sections, one being a major section 52, which contains the maximum volume obtainable, and the other being a minor section 54, which contains the minimum volume obtainable. This same plane *P** also divides protrusion portion 18 into a first section 56 and a second section 58. The volume of cutter layer material in each cutting layer

section 52,54 and the volume of each cutter protrusion section 56,58 can be calculated. These volumes are referred to herein as $V_{cl-1}*$, $V_{cl-2}*$, $V_{p1}*$ and $V_{p2}*$, respectively (Figure 1). In this embodiment, V_{cl} and V_p again refer to the total volume of cutting layer 14 and the total volume of cutter protrusion portion 18, respectively. Using the foregoing definitions, a preferred embodiment of the present invention can be described as a cutter element having a substrate surface and a cutting layer that have a shape such that the volume of the major portion of the cutting layer to the total volume of the cutting layer ($V_{cl-1}*/V_{cl-total}$) is at least 60 percent, more preferably 60 to 98 percent, and still more preferably 75 to 98 percent. Alternatively, an embodiment is contemplated wherein the ratio $V_{cl-1}* : V_{p-1}*$ is at least 60 percent and more preferably at least 70 percent and the ratio $V_{cl-1}* : V_{p-1}*$ is greater than the ratio $V_{cl-2}* : V_{p-2}*$. Each of the foregoing embodiments contemplates a degree of asymmetry in the thickness of the cutting layer.

When the distribution of the ultrahard layer on the substrate becomes less symmetrical, and particularly when one region of the cutting layer is made thicker than the surrounding regions, the likelihood of delamination typically increases. In the present case, however, it has been discovered that the shape of the diamond/substrate interface can be designed so as to minimise this potential risk. More particularly, mathematical and mechanics models are used to optimise the shape of the interface. The resulting interface shape depends on the desired shape of the outer surface and the various properties and manufacturing history of the materials of the cutting layer and so cannot be described with particularity.

Nevertheless, the underlying equations that allow optimisation of the interface shape are as follows:

(1) $$\sigma_{ij,j} + F_i = \rho \ddot{u}_i ,$$

(2) $$\varepsilon_{ij} = \tfrac{1}{2} (u_{i,j} + u_{j,i}) ,$$

(3) $$\sigma_{ij} = \delta_{ij}\lambda\varepsilon_{kk} + 2\mu\varepsilon_{ij} - \delta_{ij}q(T-T_o), \text{ and}$$

(4) $$hT,mm = \rho c_E(dT/dt),$$

where σ_{ij} is a stress tensor, ε_{ij} is a strain tensor, u_i is a displacement component, $\ddot{u}_i$ is the second derivative of u_i with respect to time, T is the temperature, dT/dt is the first derivative of T with respect to time, F is the body force, and δ_{ij} is the Kronecker delta. The balance of the symbols, h, ρ, c_E, q, λ, and μ are physical constants. Various software packages are commercially available that are capable of using the foregoing equations in combination with finite element analysis to calculate the stress and strain distributions for a given material set, temperature, geometry, boundaries and load, as will be recognised by those skilled in the art. Optimising the shape of the cutting layer can result in a reduction of the tensile contact stress by about 20-40% and can keep residual stresses at an acceptable level. The maximum thickness. For example, for an insert with a 0.44 inch (approx. 11mm) diameter and 0.163 inch (approx. 4.1mm) extension height, the thickness of a coating layer for a semi-round top cutting element with a certain smooth non-symmetrical substrate can be can be about 0.096 inch (approx. 2.4mm).

As discussed above, the cutting layer of the present invention can comprise abrasive particles such as polycrystalline diamond or any other superhard abrasive, such as cubic boron nitride, diamond composite, etc. As used in this specification, the term polycrystalline diamond, along with its abbreviation "PCD", refers to the material produced by subjecting individual diamond crystals to sufficiently high pressure and high temperature that intercrystalline bonding occurs between adjacent diamond crystals. Generally, a catalyst/binder material such as cobalt is used to assure intercrystalline bonding. PCD is sometimes referred to in the art as "sintered diamond".

In an alternative embodiment of the present invention, the cutting layer comprises an ordered composite of diamond and a carbide material as disclosed in US-A-6063502 and entitled "Composite Construction with Oriented Microstructure", which is incorporated herein by reference in its entirety. In a preferred embodiment, the ordered composite consists of a multiple of small cells, each cell consisting of a polycrystalline diamond core surrounded by a tungsten carbide-cobalt boundary or matrix. Such a structure minimises the failure area that is vulnerable to an impact or fatigue on the cutting surface.

It will be apparent that other ordered composites can be formed, with the shapes, sizes and numbers of the tubes and bundles, the composition of the components, and the direction of orientation varying depending on the desired properties of the composite.

In another alternative embodiment of the present invention, the cutting layer comprises a composite mixture of polycrystalline diamond and precemented tungsten carbide/cobalt, with a preferred ratio being 60 percent PCD and 40 percent precemented tungsten carbide/cobalt. This particular composition has a greater impact resistance and acceptable wear resistance for many applications, particularly roller cone rock bits, where wear is not a typical failure mode with conventional diamond coated inserts. It has been found in laboratory impact testing that the use of one- and two-transition layer composite diamond mixtures significantly reduces the size and amount of damage to the diamond cutting surface. A useful discussion of transition layers can be found at US-A-4694918 and US-A-4811801.

In addition to the foregoing, the concepts of the present invention can be used in conjunction with other techniques for improving cutter element durability and life. For example, the present cutting layer, having a region of exceptional thickness, can be combined with one or more transition layers. Suitable transitional layers include materials having a hardness that is intermediate that of the cutting layer and that of the substrate. Alternatively, the present cutting layer can be combined with additional layers in a manner than provides a cutter element in which at least one of the layers is harder than at least one of the layers above it. The layers can further include one or more layers of polycrystalline diamond and can include a layer in which the composition of the material changes with distance from the substrate. In addition the present cutting layer can be designed, or combined with a layer that is designed, to include a region

of residual compressive stress at its outer surface, which functions as a preload or prestress so as to offset the effect of localised loading due to contact with the formation during drilling. Further, the thickness of the transition layer(s) may vary across the substrate surface and the thickest portion of the transition layer may or may not coincide with the thickest portion of the cutting layer.

The various embodiments illustrated in Figures 1 and 4-6 include interface shapes that have been optimised for the various cutter element shapes. It will be understood, however, that the cutter element shapes to which the principles of the present invention can be applied are not limited to the embodiments shown. For example, the basic external shape of the cutter element can vary, and can be SRT, conical, chisel-shaped or relieved, and can have positive or negative draft. In addition, the shape of the interface surface of the cutting layer can vary from those illustrated. In each instance, the preferred embodiment of the present invention contemplates balancing the residual stresses with the mechanical load distribution to optimise the shape of the interface between the cutting layer and the substrate. This optimisation allows substantial gains to be made in the localised enhancement of the cutting layer, thereby increasing cutter life.

While the cutter elements of the present invention have been described according to the preferred embodiments, it will be understood that departures can be made from some aspects of the foregoing description without departing from the scope of the present invention. For example, whilst the outer abrasive cutting surface of the cutting element

is described in terms of a polycrystalline diamond layer, cubic boron nitride or wurtzite boron nitride or a combination of any of these superhard abrasive materials are also useful for the cutting surface or plane of the abrasive cutting element. Likewise, whilst the preferred substrate material comprises cemented or sintered carbide of one of the Group IVB, VB and VIB metals, which are generally pressed or sintered in the presence of a binder of cobalt, nickel, or iron or the alloys thereof, it will be understood that alternative suitable substrate materials can be used.

CLAIMS

1. A cutter element for use in a drill bit, the cutter element comprising:

a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and,

a superhard cutting layer affixed to the extension portion, the cutting layer covering the substrate apex and defining an interface surface on the extension portion, the interface surface being free of edges underneath the cutting layer, the cutting layer having a cutting surface that defines a cutting apex;

wherein the cutting layer and the extension portion have a shape such that a plane can be passed through the insert axis to divide the cutting layer where the volume of the cutting layer on a first side of the plane is at least 60 percent of the total volume of the cutting layer.

2. A cutter element according to claim 1, wherein the substrate apex is offset from the insert axis.

3. A cutter element according to claim 1 or claim 2, wherein the cutting layer comprises at least two layers.

4. A cutter element for use in a drill bit, the cutter element comprising:

a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and,

a superhard cutting layer affixed to the extension portion to define an interface surface on the extension portion and having a cutting surface;

wherein the cutting layer and the extension portion have a shape such that a plane can be passed through the insert axis to divide the cutting layer such that the volume of cutting layer on one side of the plane is at least 60 percent of the total volume of the cutting layer and wherein the cutting surface is axisymmetric.

5. A cutter element according to claim 4, wherein the cutting surface is hemispherical.

6. A cutter element according to claim 4 or claim 5, wherein the cutting layer comprises at least two layers.

7. A cutter element for use in a drill bit, the cutter element comprising:

a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and,

a superhard cutting layer affixed to the extension portion to define an interface surface on the extension portion and having a cutting surface;

wherein the cutting layer and the extension portion have a shape such that a plane can be passed through the insert axis to divide the cutting layer such that the volume of cutting layer on one side of the plane is at least 60 percent of the total volume of the cutting layer and wherein the cutting surface is free of cutting edges.

8. A cutter element according to claim 7, wherein the cutting layer comprises at least two layers.

9. A cutter element for use in a drill bit, the cutter element comprising:

a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and,

a superhard cutting layer affixed to the extension portion to define an interface surface on the extension portion and having a cutting surface defining a cutting apex;

wherein the cutting layer and the extension portion have a shape such that a plane can be passed through the insert axis to divide the cutting layer such that the volume of the cutting layer on a first side of the plane is at least 75 percent of the total volume of the cutting layer.

10. A cutter element according to claim 9, wherein the cutting layer comprises at least two layers.

11. A cutter element for use in a drill bit, the cutter element comprising:

a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and,

a superhard cutting layer affixed to the extension portion so as to define an interface surface on the extension portion and having a cutting surface defining a cutting apex that is offset from the substrate apex, the cutting layer covering the substrate apex;

wherein the substrate and the cutting layer have a shape such that the insert axis does not pass through the substrate apex and such that a plane parallel to the insert axis can be passed through the substrate apex to divide the cutting layer such that the volume of the cutting layer on a first side of the plane is at least 75 percent of the total volume of the cutting layer.

12. A cutter element according to claim 11, wherein the cutting layer comprises at least two layers.

13. A cutter element for use in a drill bit, the cutter element comprising:

a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and,

a superhard cutting layer affixed to the extension portion, the cutting layer covering the substrate apex;

wherein the substrate and the cutting layer have a shape such that a plane parallel to the insert axis and passing through the first apex divides the cutting layer such that the volume of the cutting layer on a first side of the plane is at least 60 percent of the total volume of the cutting layer; and,

wherein the cutting surface is axisymmetric.

14. A cutter element according to claim 13, wherein the volume of the cutting layer on a first side of the plane is at least 75 percent of the total volume of the cutting layer.

15. A cutter element according to claim 13 or claim 14, wherein the cutting layer comprises at least two layers.

16. A cutter element according to any of claims 13 to 15, wherein the cutting surface is hemispherical.

17. A cutter element for use in a drill bit, the cutter element comprising:

a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and,

a superhard cutting layer affixed to the extension portion;

wherein the substrate and the cutting layer have a shape such that a plane parallel to the insert axis and passing through the first apex divides the cutting layer such that the volume of the cutting layer on a first side of the plane is at least 60 percent of the total volume of the cutting layer; and,

wherein the cutting surface is free of cutting edges.

18. A cutter element according to claim 17, wherein the volume of the cutting layer on a first side of the plane is at least 75 percent of the total volume of the cutting layer

19. A cutter element according to claim 17 or claim 18, wherein the cutting layer comprises at least two layers.

20. A cutter element for use in a drill bit, the cutter element comprising:

a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis, the extension portion having a volume V_{ext}; and,

a superhard cutting layer affixed to the extension portion so as to define an interface surface on the extension portion and having a cutting surface defining a cutting apex, the entire cutting layer having a volume V_{cl};

the extension portion and the cutting layer being configured such that a plane *P** can be passed through the insert axis such that the ratio of the volume of the cutting layer on a first side of the plane *P** to the total volume on the first side of the plane $(V_{cl-1}^* : (V_{ext-1}^* + V_{cl-1}^*))$ is at least 60 percent and less than 98% and the same ratio $(V_{cl-1}^* : (V_{ext-1}^* + V_{cl-1}^*))$ is greater than a corresponding ratio on a second side of the plane $(V_{cl-2}^* : (V_{ext-2}^* + V_{cl-1}^*))$;

and wherein the volume on the first side of the plane, V_{cl-1}^*, is at least 60 percent of the the total cutting layer volume, V_{cl}.

21. A cutter element according to claim 20, wherein the ratio of the volume of the cutting layer on a first side of the plane *P** to the total volume on the first side of the plane $(V_{cl-1}^* : (V_{ext-1}^* + V_{cl-1}^*))$ is at least 75 percent.

22. A cutter element according to claim 20 or claim 21, wherein the ratio of the volume of the cutting layer on a first side of the plane *P** to the total volume on the first side of the plane $(V_{cl-1}^* : (V_{ext-1}^* + V_{cl-1}^*))$ is less than 80 percent.

23. A cutter element according to any of claims 20 to 22, wherein the cutting layer comprises at least two layers.

24. A cutter element for use in a drill bit, the cutter element comprising:

a substrate comprising a grip portion and an extension portion, the grip portion having an insert axis and the extension portion having a substrate apex; and,

a superhard cutting layer affixed to the extension portion so as to define an interface surface and having a chisel-shape cutting surface;

wherein the substrate and the cutting layer have a shape such that a plane that includes the insert axis divides the cutting layer such that the volume of the cutting layer on a first side of the plane is at least 60 percent of the total volume of the cutting layer.

25. A cutter element according to claim 24, wherein a crest of the cutter element is inclined relative to the plane of intersection between the grip portion and the extension portion.

26. A cutter element according to claim 24 or claim 25, wherein the cutting layer comprises at least two layers.

27. A cutter element according to any of claims 24 to 26, wherein volume of the cutting layer on a first side of the plane is at least 75 percent of the total volume of the cutting layer.

28. A cutter element for use in a drill bit, substantially in accordance with any of the examples as hereinbefore

described with reference to and as illustrated by the accompanying drawings.

Application No: GB 0030664.7
Claims searched: 1 - 10, 24 - 27

Examiner: Eleanor Wade
Date of search: 18 April 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): E1F FGA, FGC

Int Cl (Ed.7): E21B

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2334278	Smith Int. see fig 5a, 6a,b,d, 7a,e, 8a,c,e	1
A	EP0692607	De Beers Ind Diamond	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.